The 2007 emerging corn price surge revisited – Was it expected or a large surprise?

Jochen Schmitz* and Oliver von Ledebur*

Affiliations:
*	Johann Heinrich von Thünen Institute (vTI), Braunschweig, Germany

Corresponding author:
Oliver von Ledebur
Johann Heinrich von Thünen Institute (vTI)
Bundesallee 50
D-36118 Braunschweig
Germany
Phone: +49-531-596-5323
Fax: +49-531-596-5399
Email: oliver.ledebur@vti.bund.de

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Abstract

Point forecasts are a common method to classify uncertain future outcomes. In the option price literature the concept of implied volatility is well known. This concept is used to get a forward looking indicator about the future volatility. Nowadays market expectations can be extracted in numerous ways. One of the first articles regarding this topic in the area of exchange rates and interest rates was Sölderlind and Svensson (1997). Extracting market expectations is not only focused on point forecasts. A more ambitious approach is to extract the whole possible range of market expectations out of option prices. This concept is called risk-neutral density (RND).

Most agricultural markets undergo some remarkable price movements in the last 4 years. The reasons for sharp price swings in the oilseed markets are controversial discussed. This article link new econometric concepts and agricultural markets together. It broadens the understanding of market activity at a specific time period. The obtained futures price expectations map a clear picture of trading activity. The accuracy of the price expectation, an important issue for analysts and the policy, is satisfying. Areas of further work can certainly be found in the analysis of different time ranges, other product markets and exchanges.

Keywords: risk neutral density, market expectations, futures prices, corn market

JEL Classification: Q14, C53, C58, G17

1 Introduction

A challenging forecasting problem is to use market information to produce an estimate for a future asset price. Especially central banks are interested in using market expectations to evaluate the effectiveness of interventions. Extracting a point forecast out of market data is only the first step. A complete description of the whole probability density for future asset prices is desirable. Probability densities for future asset prices can be obtained from prices of options. This concept is called risk-neutral density (RND).

One of the first articles regarding this topic was Sölderlind and Svensson (1997). They applied this concept on interest rate expectations, exchange rate expectations and inflation expectations. Some central banks picked up on this concept and used it for market analysis and policy recommendations. Among these were the Reserve Bank of Australia (Bahr and Chiarella, 2000) and the European Central Bank (Hördahl and Vestin, 2005). A list of several studies that use implied RND's to evaluate market expectations concerning economic and political events can be found in (Bliss and Panigirtzoglou, 2002). In the last years several econometric methods were developed to extract market expectations to get RND's. A review of those methods can be found in (Taylor, 2005, pp.428-458). RND's are now frequently used in financial market analysis.

To the best of our knowledge, the first, and so far only, article that links option-based probability assessments and agricultural markets is Fackler and King (1990). Closing the gap between financial market analysis and agricultural market analysis is one ambition of this study. The added value of this analysis is two-fold. First, it allows a more detailed look in the expectations of market stakeholders at a specific period of time. Second, this econometric tool allows interventions to be evaluated. It therefore may guide policy decision-makers in the decision-making process. The value of a prospective policy-analysis tool which extracts the market sentiment should not be underestimated.

2 Data

The data basis for this analysis is end-of-day data for corn from the Chicago Board of Trade (CBOT). We take the December 2007 maturity futures contract as our starting point. The RND's should therefore reveal the market sentiment in December 2007. Additional data on options on futures is also needed to calculate the RND. Both time series (futures and option on futures) were acquired by the CME Group. The risk-free rate was provided by the Board of

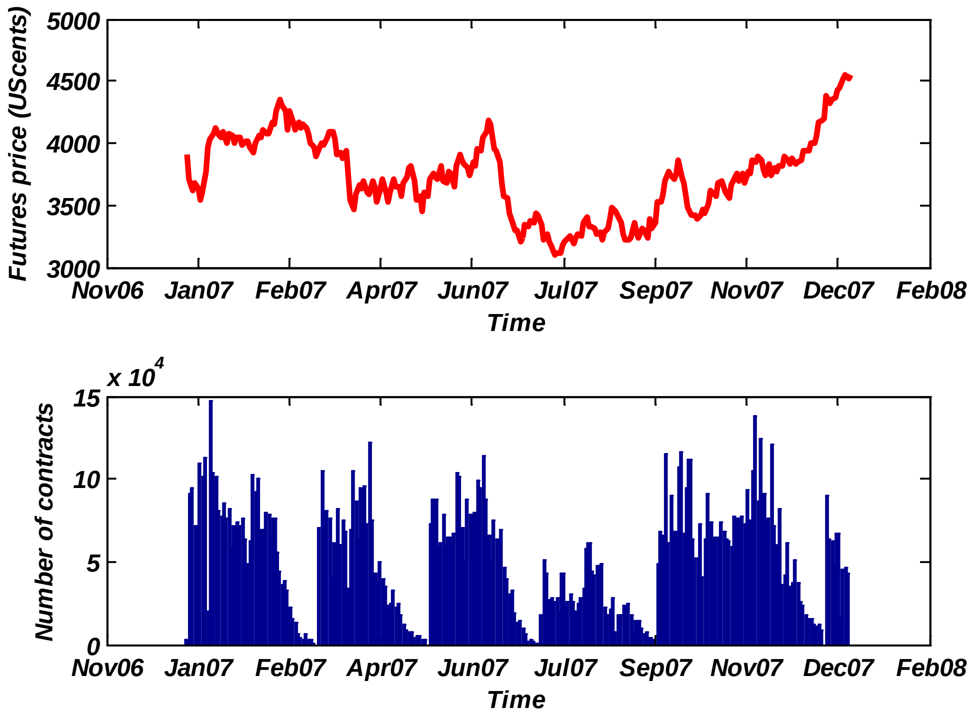
Governors of the Federal Reserve System. We selected the 10-year treasury rate (Series H15) as a good approximation for the risk-free rate. The contract size of one corn option on futures is 5000 bushels. These are approximately 127 metric tonnes. The pricing unit is cents per bushel.

Option on futures contracts are initiated by CBOT almost 2 years before date of expiry. Little or no trading takes place in the first year of maturity. No information can be extracted during this period of time. Due to this we focus only on the second year of maturity or more precisely 252 trading days (1. Jan. 2007 – 31. Dec. 2007).

The futures price development and the trading volume in 2007 is shown in Figure 1. The top panel shows the futures price pattern. One can clearly see a sharp drop between June and July. Starting in November 2007, one can see also the beginning of a price surge. This finally results in a price peak in 2008.

The bottom panel shows the corresponding daily trading volume. After each second month, a sharp drop in trading activity emerged. This is due to the fact that this time series has been constructed using futures prices from the nearest maturity contract. As the listed futures quotations at CBOT do not always match the option on futures maturity, a continuous futures price series for analysis is called for. This has been done by always using the nearest maturity contract for this time series. As the expiration date comes closer, the trading volume declines. Trading such a contract is becoming more and more unattractive. This behavior can be seen in the lower panel.

Figure 1 : Nearest Futures price development in 2007



Source: data from CME/CBOT

To ensure a smooth RND (and a smooth call price function) the options data need to fulfill specific properties. Option prices that violated the monotonicity or convexity properties were discarded. Monotonicity requires that the call (put) prices are strictly decreasing (increasing) with respect to the exercise price. Convexity requires that a butterfly spread at a particular strike (formed by selling two call options at this strike and buying the two adjacent call options) is positive. In a continuum of strikes, this is equivalent to require that the call and put price function are convex. The monotonic and convexity property ensure a non-negative probability of the RND's.

Following Bliss and Panigirtzoglou (2002) only out-of-the money call (future price lower than strike price) and put (future price greater than strike price) options prices were used, because there is usually more trading in these, rather than in-the-money, options[1]. Option prices for which the implied volatility was impossible to compute or was, with deltas, smaller than 0.01 or greater as 0.99 (far out-of-the money options with usually little or no trading) were also discarded. The terms implied volatility and delta are closely related to the Black-Scholes option price concept (Black, 1976). A more detailed specification of the underlying approach

[1] Conversely for in the money option call the future price is greater than the strike price and for the in the money option put the future price is lower than strike price.

is given in the next section. Further, all options with a negative or zero prices were not included in the estimation of RND's. The last important characteristic is the trading volume. If the trading volume is zero, the clearinghouse is going to find a settlement price. In this case there is no market information to extract. Only options with a trading volume of larger than zero are going to be included in the estimation. If after this data elimination less than 3 strike prices were available, no RND will be estimated.

The number of options listed each day varies. Most of the options were discarded each day after the above mentioned data adjustment. Only a small number of cross section options remain to calculate the RND. The trading volume condition and the delta boundaries were the two most important obstacles preventing us from using more options.

To give a short insight into the options on futures data, Table 1 gives an exemplary descriptive summary before the data adjustment. On that particular day 137 options were listed. But only a few of them were also actively traded. One interesting feature of this data is the wide range of listed strike prices for both call and put options. After the data was cleaned up, only a few options remained. As one can see from the so called 'volatility smile' (see Figure 3), a total of 18 options was available to reveal the volatility smile.

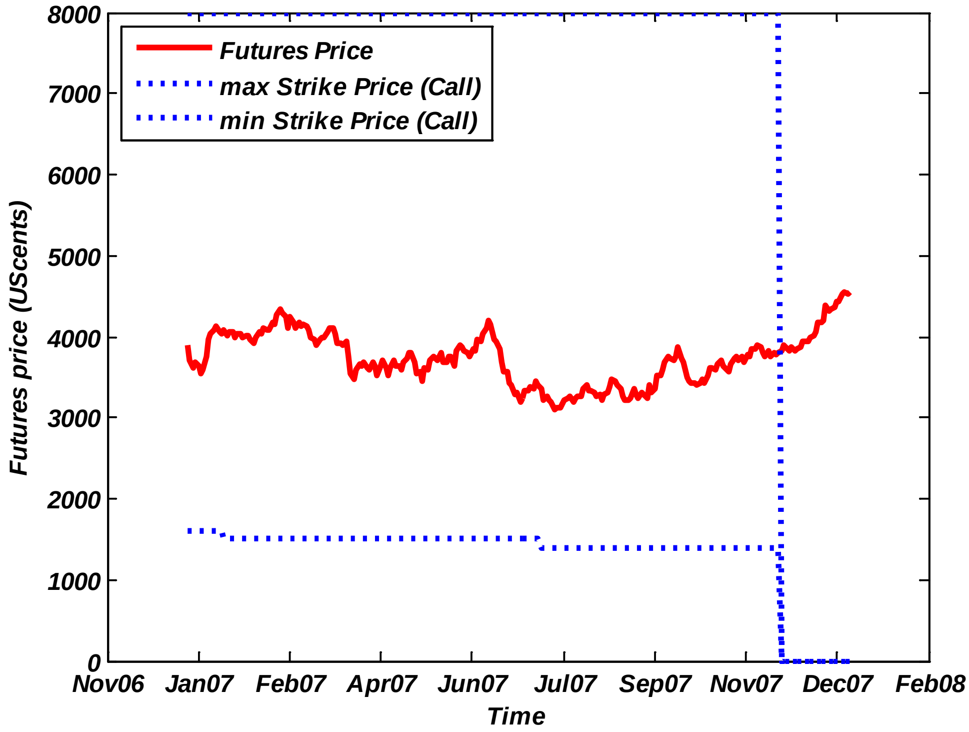
Table 1: Summary of descriptive statistic for the corn options on futures for Oct. 8, 2007

No. Call	81
No. Put	56
Futures price	3396
Risk-free rate	4,65%
Total trading Volume	26682
max Strike price (Call)	8000
min Strike price (Call)	1400
max Strike price (Put)	8000
min Strike price (Put)	2200

Source: own calculations.

The range of listed strike prices was nearly constant in 2007. The maximum strike price level was 8000 cents. The minimum strike price was around 1400 cents with minor adjustments. Despite the December 2007 (beginning of the price surge) this year was a fairly normal year in terms of futures price development. No major listed strike price adjustment was called for. In mid-November no December 2007 maturity contract has been traded anymore. So the blue dotted line in Figure 2 collapse to zero.

Figure 2: Range of strike price in 2007



Source: own calculations.

3 Method

The work of Breeden and Litzenberger (1978) builds the core result of the risk-neutral densities literature. They showed that the risk-neutral density (RND) is contained within option prices. This implicit distribution function, denoted below as *g*, can be recovered by calculating the second partial derivative of the Black and Scholes call option price function *c* with respect to the strike price *K*:

$$\frac{\delta^2 c}{\delta K^2} = e^{-r\tau} g(S_T) \qquad (1)$$

The variables r and τ are the risk-free interest rate and the maturity of the option. The expression (S_T) is the underlying spot price, in this case the futures price, at the time of expiration T. In theory, this result requires a continuum of option prices with different strike prices which is not available. Only a limited number of strike prices for one option with the same maturity are accessible. To construct a smooth call price function one needs to interpolate between these call price/strike price data pairs. Shimko (1993) and Malz (1997) were the first authors who argued that the call price function can, in general, be made even smoother by interpolating implied volatilities/delta data pairs instead of pairs of call prices/strike prices. Bliss and Panigirtzoglou (2002) also adopted this approach. In this study we also follow this approach to create a smooth call price function. Several steps are needed to construct this.

A suited option pricing formula is needed to calculate implied volatilities. A commonly used pricing formula for commodities is the Black (1976) model. The model is widely used for modeling options on physical commodities, forwards or futures. The premium d_1 for call options (c) and d_2 for put options (p) can be deduced:

$$c = e^{-r\tau}[FN(d_1) - KN(d_2)]$$

$$p = e^{-r\tau}[KN(-d_2) - FN(-d_1)]$$

$$d_1 = \frac{ln(F/K) + (\sigma^2/2)\tau}{\sigma\sqrt{\tau}}$$

$$d_2 = \frac{ln(F/K) - (\sigma^2/2)\tau}{\sigma\sqrt{\tau}}$$

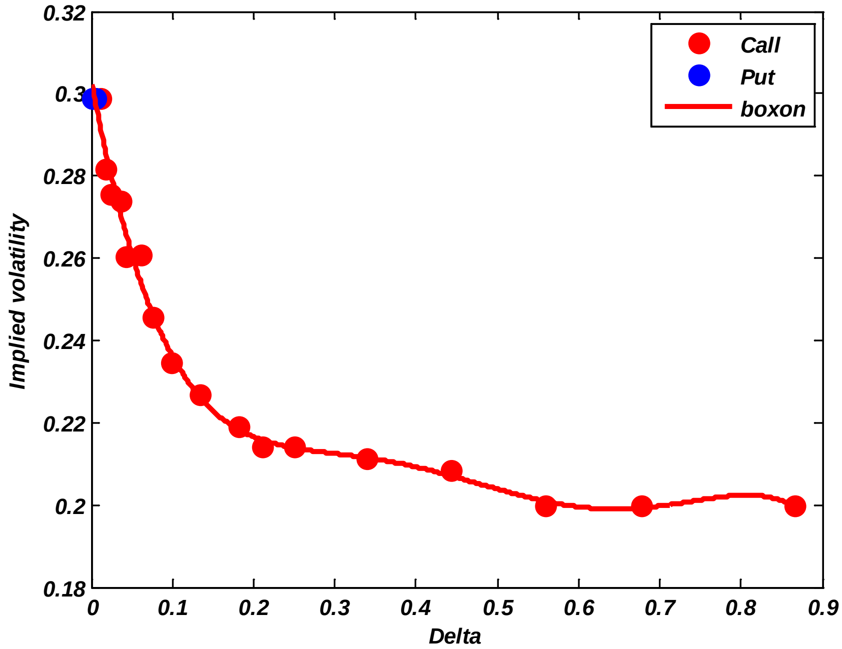
Given the usual information like current futures price (F), the strike price (K), maturity (τ) and risk-free rate (r) one can easily calculate the implied volatility (σ_{impl}) (e.g. Newton-Raphson method). Also one can calculate the option's delta (Δ_c, Δ_p) for a given option. This measure gives an indication of the option's reaction if the underlying basis is changing by one unit.

$$\Delta_c = \frac{\partial c}{\partial F} \; ; \; \Delta_p = \frac{\partial p}{\partial F}$$

Normally only a limited number of strike prices are available for one option. This price range does extend far into the tails of the RND. Our main interest lies in the center of the distribution. We want to elaborate how good the RND can predict future price movements. We choose to assume the tail distributions were log-normal and therefore following Bliss and Panigirtzoglou (2004). This assumption is sufficient for this purpose. Figlewski (2010) uses extreme value theory to construct the tails of RND. This can also be incorporated in a further study.

After transforming the pairs of call prices/strike prices into implied volatilities/delta data pairs, and assuming an appropriate tail distribution, one can interpolate the data points to get the so-called volatility smile curve (see the boxon line in Figure 3). Here a fifth order polynominal is fitted to the implied volatilities/delta data pairs.

Figure 3: Volatility Smile, 8.Oct. 2007



Source: own calculations.

This fitted function can now be used to build a continuum of implied volatilities. 1000 implied volatilities/delta data pairs are generated by using the fitted function. Only one additional step is needed for a smooth call price function. A transformation back to premium/strike price values using the Black (1976) formula is required. The result is a smooth call price function which consists now of 1000 data points. This function can numerically differentiate twice with respect to the strike price to get the risk-neutral density function.

4 Results

As the calculations provide a huge amount of results, we focus on the discussion of the obtained RND, based on 12 usable outputs, which gives us a monthly rhythm that can be confronted with the evolution of the corn futures prices (upper graph in Figure 1). In the following Table 2, we depict representative daily RND's from January to June (June 1st) and in Table 3 from June (June 5th) to November of 2007. Due to the available data and the implemented adjustment procedure (as described in Section 2), it was not possible to construct a continuous RND for each day. In cases where we got a continuous time period (e.g. 14 days) the obtained RND's do not vary significantly on a daily basis.

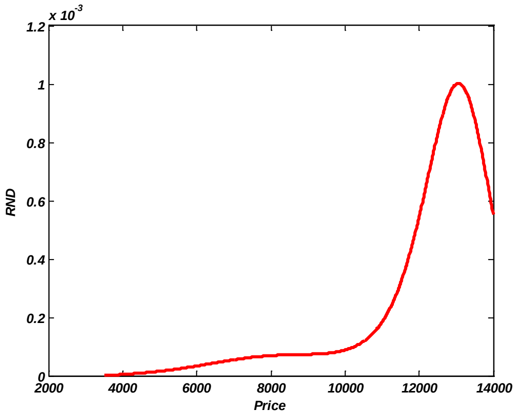
The monthly 'Feed Outlook' and the 'Grain: World Markets and Trade' reports of the USDA[2] take a prominent role in building market expectations. At the day of its release the related markets do react to its content. A monthly approach and discussion has therefore been chosen here.

The RND interpretation will start with the top left panel for January in Table 2. In January 2007 the range of expected possible outcomes was extremely wide. It covered price expectations from around 4000 cents per bushel to 14000 cents per bushel. Those market stakeholders who expected a futures price of about 4000 cents per bushel were in the minority. This can be seen as there is only a very small probability mass around 4000. The mean expectation (highest probability mass) was around 13000 cents per bushel. The extremely high levels cannot be explained. It seems from this picture that the market expectations were extremely diffuse one year before contract expiration. In the following months this picture changed completely.

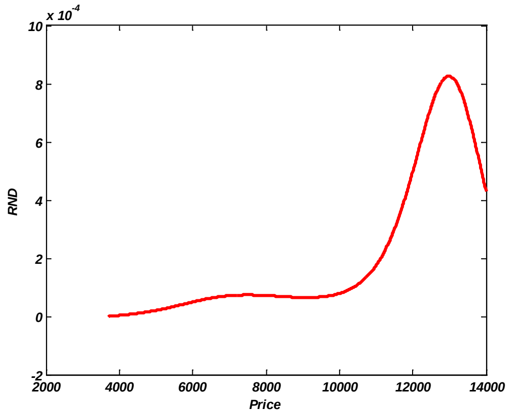
With some variation of the expected price range after February, this basically repeats the January picture, the period of March to June begins to show that the market stakeholder's expectations remain diffuse with the range for the futures price expected to be between 4000 and 11000 cents per bushel. The mean expectation until then is found between 10000 and 11000 cents.

[2] http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1273 and http://www.fas.usda.gov/grain_arc.asp

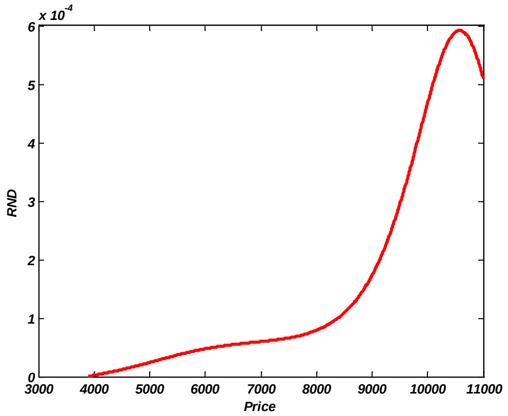
Table 2: RND's for corn futures (December contract), January to June of 2007



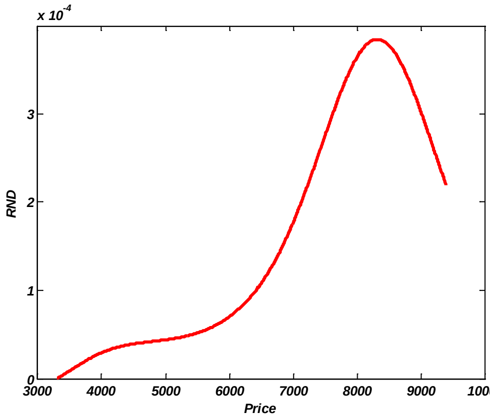
03. January 2007



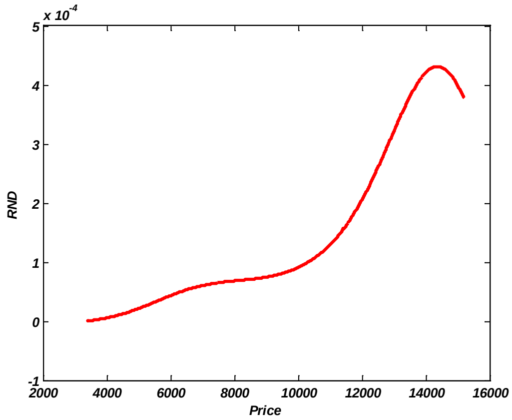
01. February 2007



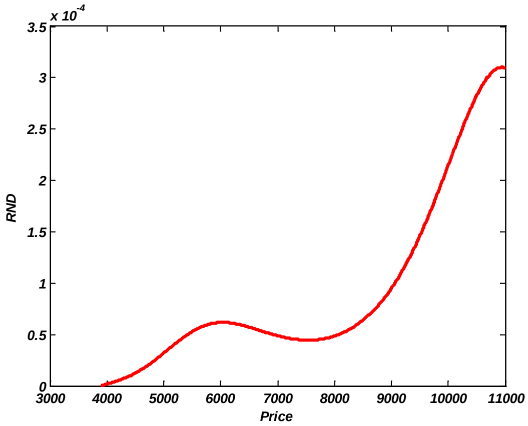
02. March 2007



02.April 2007



01.May 2007



01.June 2007

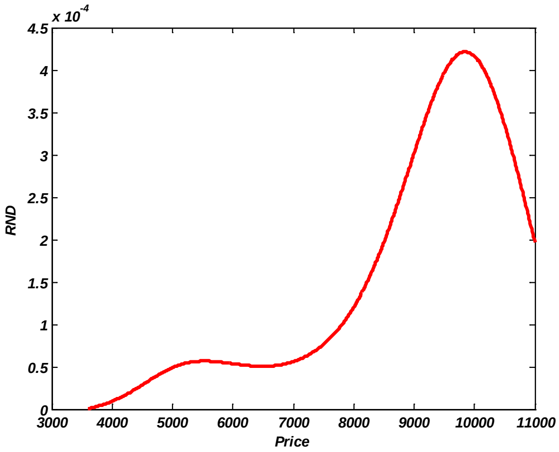
Source: own calculations.

The outcome for May differs from the surrounding months by showing a wider price range and a return to higher prices expectations. This might be caused by the unclear market information situation since there was no 'Feed Outlook' report scheduled for April by the USDA. In this timeframe the futures market price was ranging at a level of about 3750 cents. After the March releases of two reports, the USDA report of May highlights the record production forecast for 2007/08 and record corn use propelled by Ethanol production. The focus of the World Markets and Trade report in May can be illustrated with the heading "Despite A Record Global Grain Crop Forecast, Stocks Are Still Expected To Shrink In 2007/08". This combined information (or its anticipation by the market) was probably one cause for the notable increase in price expectations in this month when comparing to the previous months, where the expected price range decreases. In June, the expected price range decreases again and for the first time a separation of expectations is noticeable in two humps. One in which prices around 5500 cents per bushel were expected and one (with more probability mass) still expecting prices up to 10000 cents. Also note the massive shift of the modus from 13000 cents per bushel in January 2007 down to now 10000 cents per bushel in June 2007.

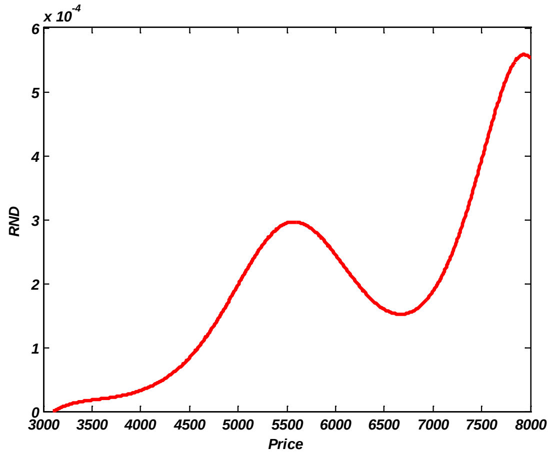
The RND plots in Table 3 show that the price at which the futures were expected to be traded at the end of the contract declines from the previous months. Additionally one can observe that option traders' lairs rudimentary recognizable in the RND for June 5th clearly separates into two distinct groups with different gravity centers from July on until September. It seems clear from the July panel in Table 3 that the market sentiment became more visible nearly 6 months prior to contract expiration. Maybe at least some of the stakeholders tried to build more realistic price expectations at this time. The October and November RND's finally show that the expectations indicate a futures price level of around 4500 cents for the December corn futures contract. As we know ex post the futures price in December 2007 increased from around 4000 cents per bushel up to 4500 cents per bushel.

Remarkably these two humps still remain in July, August and September. All three months show a similar pattern. Despite the first six months, the range of possible price outcomes drops significantly. In July the range of possible price outcomes was 3000 cents per bushel to 8000 cents per bushel. For August and September this range narrows down even more. During this time period the prices ranges only from 3000 cents per bushel to 6000 cents per bushel.

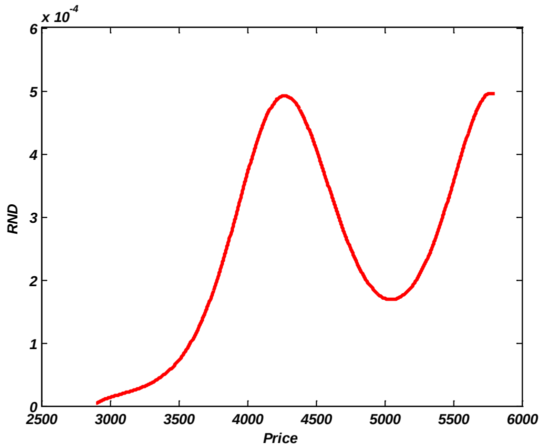
Table 3: RND's for corn futures (December contract), June to November of 2007



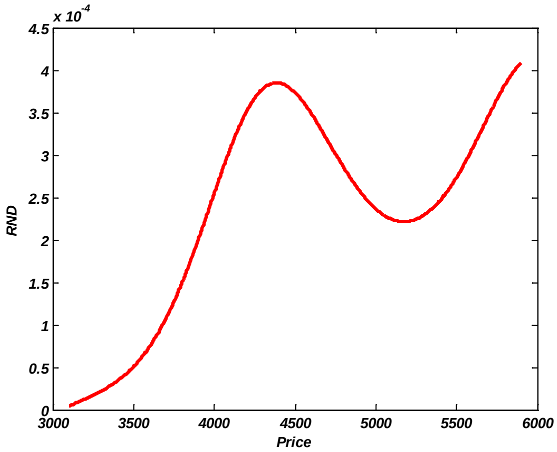
05.June 2007



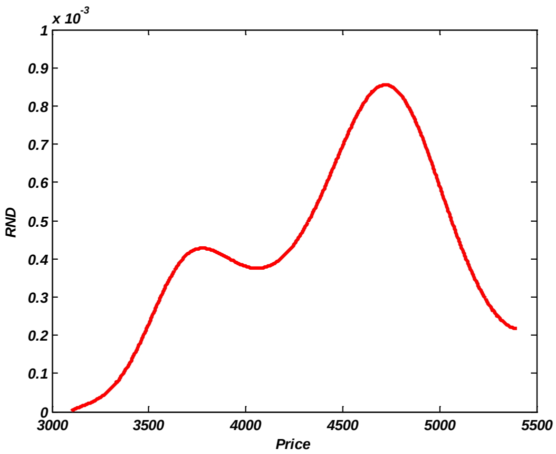
11.July 2007



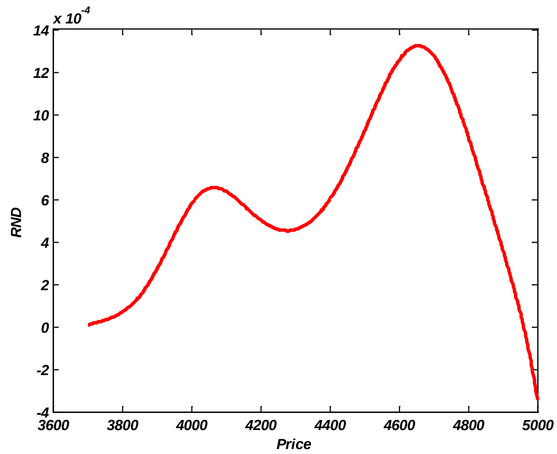
01.August 2007



04.September 2007



08. October 2007



07. November 2007

Source: own calculations.

This outcome was foreseen in July, but only by the smallest group of stakeholders. From the RND's of the subsequent months one can identify that the excessively high expectations were corrected to lower levels. While the July RND shows a maximum price expectation of 8000 cents with the bulk of probability mass on it, in the expectation on that price in August and September, the maximum price lies at 6000 cent per bushel. During these months the gravity center of the probability mass moved from the upper price level to the lower one, finally corresponding to the December futures contract price.

Typically the crop outcome estimates become more and more reliable 4 to 5 months prior to harvest. All market participants should now have far more accurate expectations about the harvest and the upcoming general weather conditions. The USDA reports are an indicator for this and also for the sentiment on possible unbalanced global supply and demand. So the market stakeholders are setting up their positions. We believe that this price rearrangement is a clear indication of this behavior.

The last two months (October and November in Table 3) became very illustrative. The lower left and right panel in Table 3 shows the RND for October and November. Both humps are still clear visible. One peak is at around 3700 cents and another at around 4800 cents in October. Two months prior to expiration the market sentiment seems very clear. And as we know now this expectation was correct. It is hard to make a clear judgment on the composition of stakeholders. Two humps would regularly indicate two separate groups of stakeholders with different expectations about the future outcome. It is a result of this study that the futures price increase in December has been anticipated by market participants. The two humps, and also the corresponding price expectation, are nearly identical to the real world price increase from 4000 cents up to 4500 cents. In November this price range between both humps is almost exactly the same as in the futures price development in December 2007.

In recent years a reinterpretation of the RND concept emerged. According to this the RND not only represents the traders' perception of (future) price movements but also includes the traders' degree of risk aversion (Ait-Sahalia et.al., 2001, Bliss and Panigirtzoglou, 2004)). It should then not be surprising that there is a risk premium in market prices. The coherence between risk-neutral densities $f_t(S_T)$ and objective (risk-adjusted) densities $f_t^*(S_T)$ is well established. Following Ait-Sahalia and Lo (2000) both densities are related by a stochastic discount factor ξ_T(sometimes referred as pricing kernel) as[3]:

[3] For a detailed derivation of the underlying dynamic equilibrium asset-price model and the above mentioned relation between both densities see Ait-Sahalia and Lo (2000) page 12-16 and page 24-29

$$\xi_T = \frac{f_t^*(S_T)}{f_t(S_T)}$$

This risk-adjusted objective density therefore contains information about investors' preferences and asset price dynamics.

In summation: the whole price expectations set up can be divided into three broad time periods. The first period, ranging from January to May, is characterized by a very diffuse expected price range. The reasons why some market stakeholders expected prices above 10,000 cents per bushel is not clear. The second period, ranging from June to September, seems to be the time where market participants built up their position in the market. The expected price range narrows down. Also this period indicates two groups with quite different price expectations. The last period, October to November, is the most interesting phase. The futures price increase seems to be anticipated by market stakeholders. It is necessary to keep in mind that the applied method focuses on the center of the RND distribution. Extreme expectations in the flanks of the risk neutral distributions may not be completely mapped.

5 Conclusions

Our analysis of the RND's for the last eleven months of the December corn futures contract show that the RND could anticipate the developments on the corn futures market. This backs the approach already established in the context of the central bank analysis for market sentiment estimation.

Three broad time periods has been identified in forming price expectations. The first one from January to May, the second from June to September and the third form October till November. The first time period is characterized by very high price expectations. The reasons for such expectations have to be analyzed further. The second period shows a more concrete mapping of expectations and gives a good grasp about the possible price range in the future. Two months before expiration the RND's shows are very clear picture of the futures price in December 2007.

The RND methodology serves as this experiment demonstrates, as an tool to foresee movements on the markets that can provide decision makers in the administration and in the private sector to an improved view of the market expectation and a better basis for decisions.

One might ask if the obtained outcome is dependent on the very particular commodity market situation on the year 2007 and the following year 2008, when prices of nearly all commodities dropped drastically. Additional research in the area of prospective price analysis is needed to validate this first outcome. The accuracy of the obtained futures price expectation, an important issue for analysts and the policy, should also be examined more accurately than in this explorative work. Areas of further research can certainly be found in the analysis of different time ranges, other product markets and exchanges. The mentioned risk-adjusted objective density contains information about investors' preferences. Also this line of research regarding agricultural futures markets offers a scope for future research.

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